Near-field study of dielectric surface lens

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Summary

In this work, we design, fabricate and experimentally characterize a surface structured lens within an ultra thin polymer layer deposited on a Bloch Surface Waves (BSWs) suspended dielectric platform. The near-field (SNOM) measurements demonstrate that the lens is able to manipulate the propagation of the surface waves. Experimental result shows good agreement with the simulation calculated using the finite difference time-domain (FDTD). This work opens a way to realize surface structured integrated all-optical systems and the study of fundamental optical phenomena.

Introduction

In recent years, we have demonstrated that a ridge of polymer with nanometric thickness on a dielectric multilayer acts as an efficient waveguide for BSWs [1]. It demonstrates the possibility to manipulate BSWs with ultra-thin polymeric structures and to realize surface optical components. Since the surface structures imply bounded surface modes, it is crucial to have access to their evanescent tail in order to observe their propagation. The MH-SNOM available in the EPFL-OPT laboratory is therefore necessary in investigating the surface structures.

In this work, the dielectric multilayer is demonstrated as a universal platform to suspend surface waves and a convex lens is structured in a 100 nm thick photoresist (AZ1518) layer coated on top of the platform. The effective indices of the BSWs in the surface lens (n_{lens} = 1.23) and the surrounding media ($n_{platform}$ = 1.18) can be derived from the obtained propagation constant at the wavelength of 1542 nm. The index difference Δn can be a key parameter for optimization as we will see in the next section.

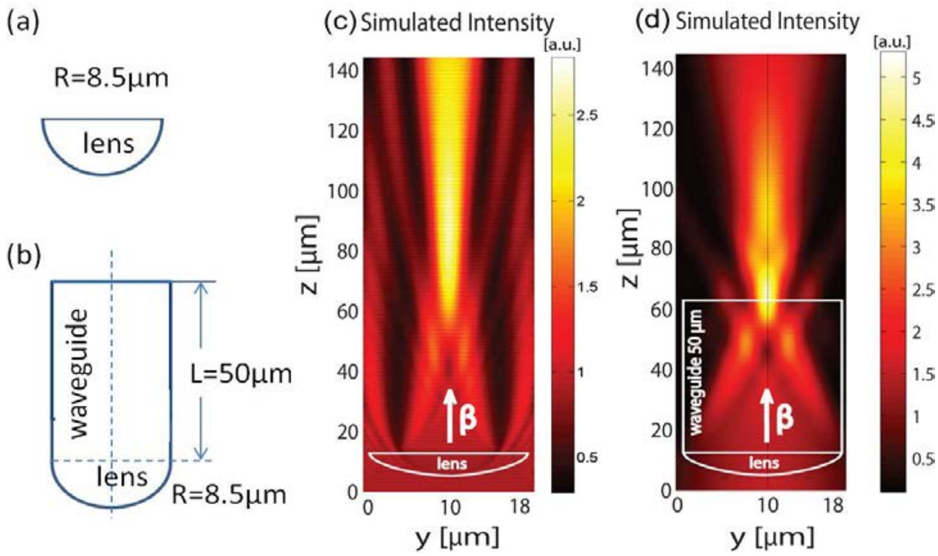

Fig. 1 (a)-(b) Model of the surface plano-convex lens appended to a waveguide. The lens radius of curvature is R = 8.5 µm. The waveguide is of width 2R and of length L= 0 µm (a) and 50 µm (b) respectively. (c)-(d) Rigorous simulation results with finite difference time-domain (FDTD) with the defined index difference at the wavelength of 1542 nm.

The model of the surface lens is appended to a waveguide as presented in Fig. 1(a)/ (b). The lens radius of curvature is R = 8.5 µm and the waveguide width is 2R. The length of the waveguide L is 0 μm/ 50 μm, respectively. The measured electric field distribution in the vicinity of the micro lens in Fig. 1(b) is in good agreement with the FDTD simulation [1]. Rigorous simulation results with FDTD on lenses in Fig. 1(a)/ (b) is shown in Fig. 1(c)/ (d) accordingly. It can be seen that the position of the maximum amplitude locates much closer to the lens compared with the geometrical predictions. This is due to diffraction which dominates the behavior of light propagation since its Fresnel number is small. Moreover, the position of the maximum amplitude moves towards the first interface of the lens while increase the length of the waveguide.

Discussion

In order to understand the principle of the surface convex lens, we theoretically study the impact of the refractive index difference between the lens layer and the platform. Figure 2 shows the FDTD simulation of a comparison of both the location and the value of the maximum amplitude position as a function of Δn for different waveguide lengths (0 μm, 30 μm and 50 μm). As shown in Fig. 2(a), the maximum amplitude position is calculated with respect to the first interface of the lens. The higher the index difference, the closer the maximum amplitude position towards the lens. The sudden shift can be attributed to the interference effects caused by the guiding structure. Figure 2(b) represents the maximum near-field amplitude normalized by the incident beam for different refractive index differences. The value of the maximum field amplitude increases by increasing the refractive index difference. Note that higher field amplitude can be obtained by increasing the waveguide lens for a given refractive index difference.

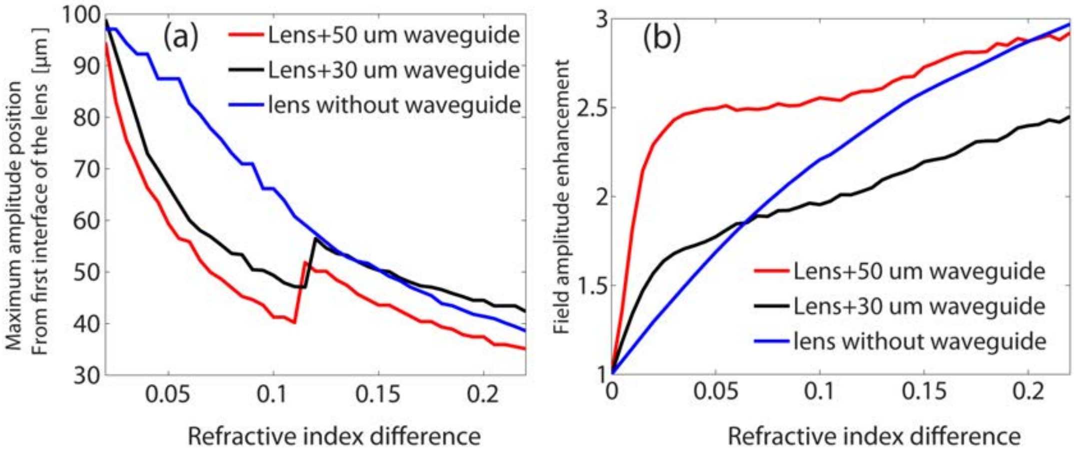

Fig 2. FDTD simulation of (a) position of the maximum amplitude with respect to the lens location verses the effective index difference between the lens and the platform. Results with different waveguide length are compared. (b) Value of the maximum field amplitude is normalized by the incident beam.

Conclusions

In this work, we experimentally and theoretically demonstrate the manipulation of the BSWs propagation through a surface plano-convex lens, which is appended to a waveguide on a dielectric multilayer. The impact of the refractive index difference and the waveguide length are also discussed. This provides a first step towards the investigation of surface all-optics systems on a BSWs platform. Experimental results are in preparation [2] and will be presented in the conference.

Reference

[1] T. Sfez, E. Descrovi, L. Yu, D. Brunazzo, M. Quaglio, L. Dominici, W. Nakagawa, F. Michelotti, F. Giorgis, O. J. F. Martin, and H. P. Herzig, "Bloch surface waves in ultrathin waveguides: near-field investigation of mode polarization and propagation," Journal of the Optical Society of America B 27, 1617 (2010).
[2] L. Yu, V. Paeder, T. Sfez, L. Hvozdara, J. D. Francesco, E. Barakat and H. P. Herzig, " Platform concept for two-dimensional optics: near-field investigations on Bloch surface waves based flat lens, prism and gratings ", paper in preparation.